HCAL: Calibration and Monitoring

From Scintillation/Cerenkov Lights to JET/MET/tau

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Issues

Lights (scint, Cerenkov) >> ADC counts >>> GeV of jets, taus, MET

HB/HE/HO

11k readout channels

100k scint. tiles

HF

2.4k readout channels

0.2M fibers

Quality control/test

(during construction)

Inter channel calibration

& monitoring

timing

gain

dead/sick channel

Time dependent calibration

radiation damage

ECAL+HACL

Non-linear response

(due to e/pi >> 1.0)

Material/cracks

tracker/cables/support/...

Pile-up

E_T=17 GeV in R<0.6 at E34

Physics

FSR: out-of-cone energy

E_T scale calibration

Calorimeter level

weights (longitudinal)

Physics object level. (jet etc.)

Et-eta dependent

Pile-up energy subtract.

Physics object dependent

Pion Response: Linearlity

ECAHL+HCAL: Non compensating calorimeter

96'H2 Teast Beam Data

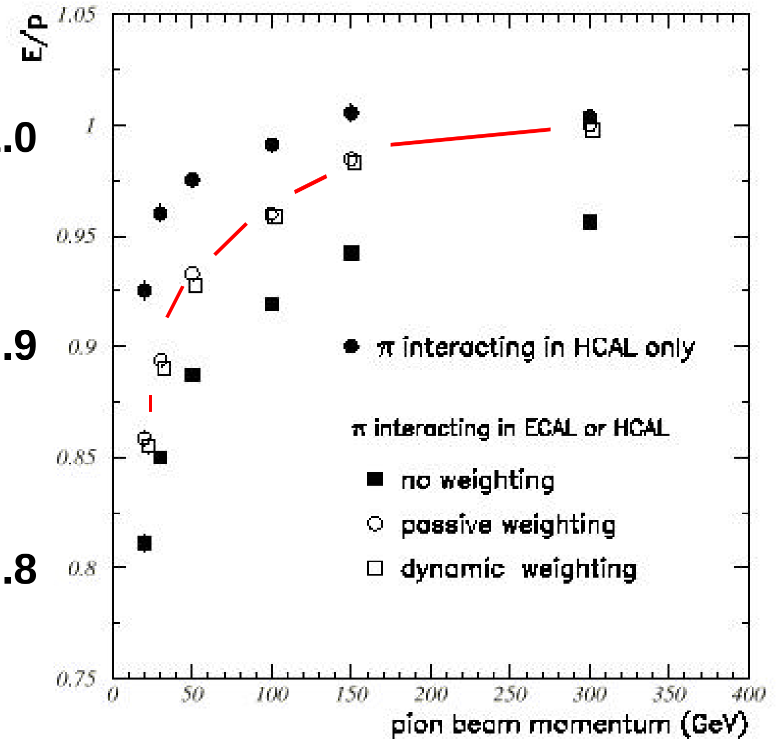
CMS Simulation

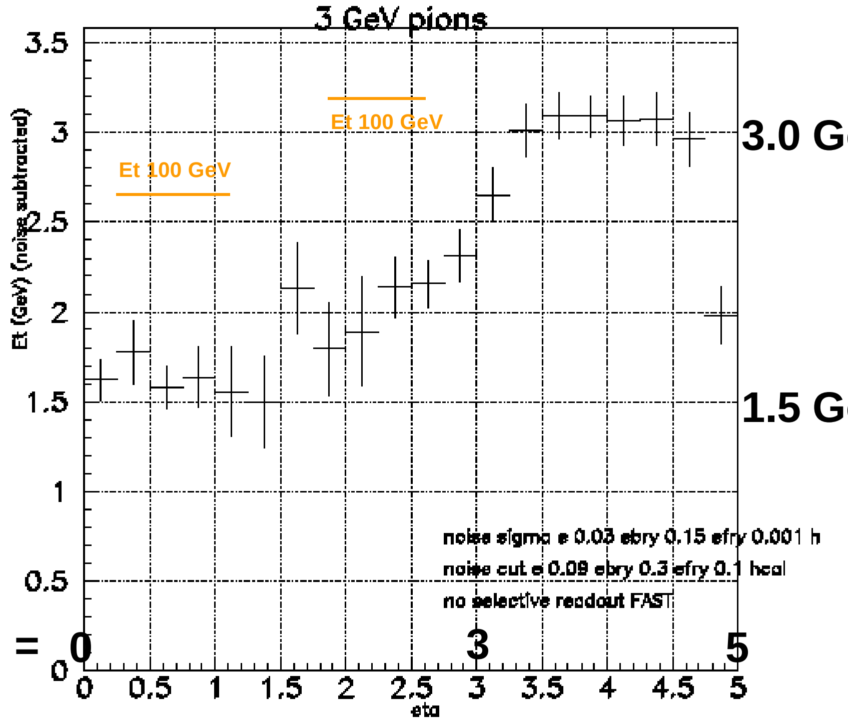
ET=3 GeV pion in 0<|η|<5

1.0

0.9

0.8





3.0 GeV

1.5 GeV

= 0 3 5

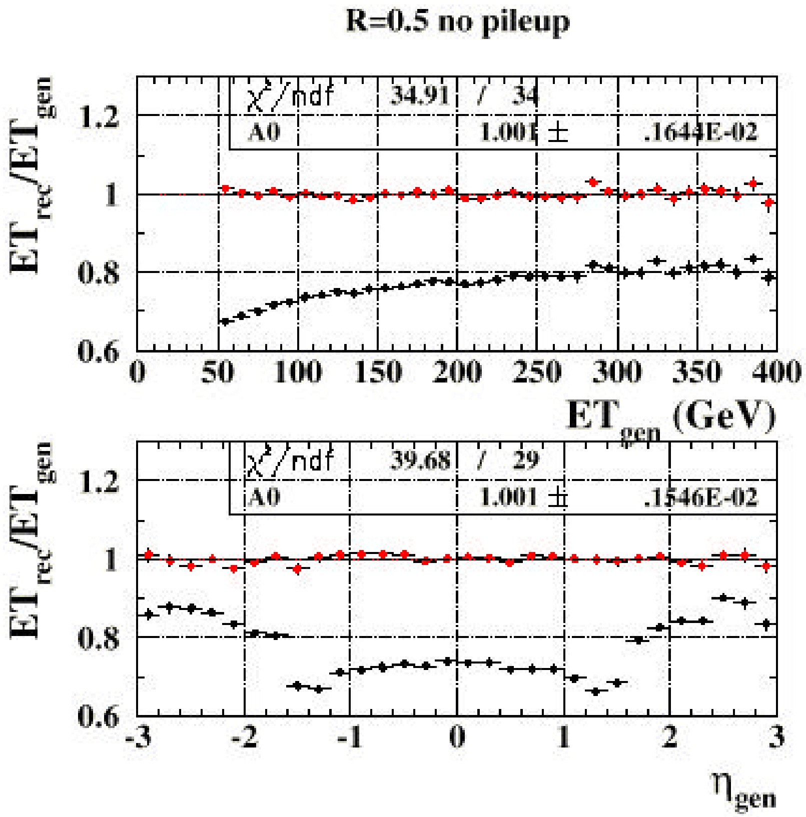
E= 3 7 30 82 227 GeV

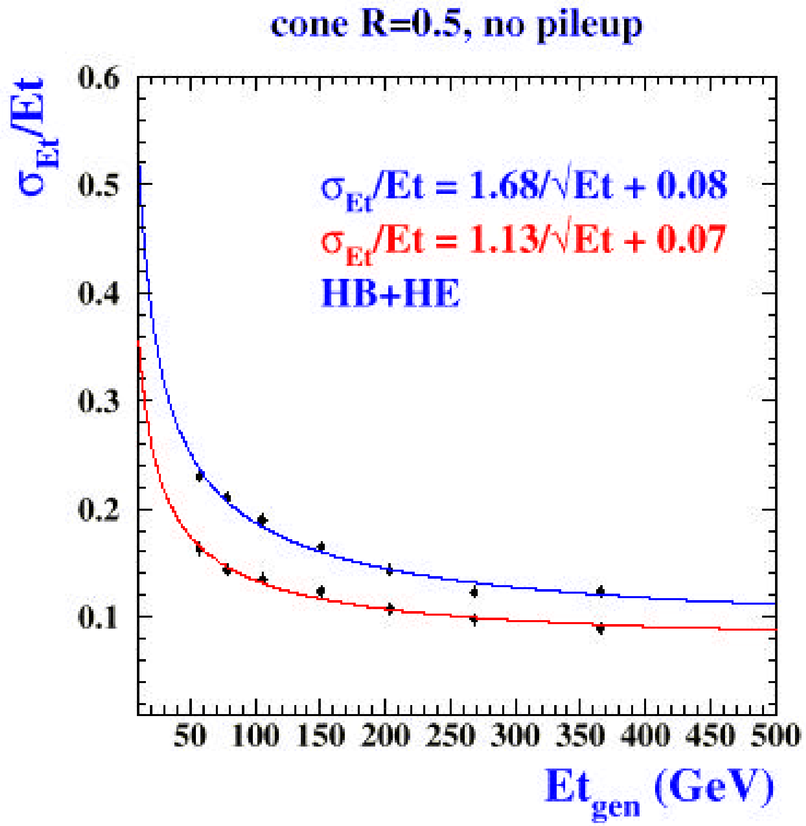
P= 0 200 400GeV

Jet Response and Correction
(CMSIM/ORCA)

Et-eta dependent correction for QCD jets

Et(corr)=a x Et(obs) + b





=> Different corrections for L1 jets, tau-jets and b-jets

=> Luminosity dependent.

LEP vs. LHC

LEP

- single mass scale
  - mass (Z) at LEP-I
- hard scattering at rest in the lab frame
  - distribution: isotropic
    - (neglecting spin, higher-order effect)

LHC

- big range in mass scale
  - from mass(Z,W, h(?)) to 1-3 TeV
- hard scattering boosted in longitudinal direction
  - Et=50GeV: E=50GeV at η=0 and E=500GeV at η=3.

.

CMS needs energy calibration for much wider range than LHP. ----- tough job! (with non-compensating calorimeter).

Data Flow

>>> front end <<<

Scint. Lights
->Tile->Fiber1&2->OptCable
->HPD->Amp->ADC->
Charge (for 5-10xings)
->(L1Path)
->(DAQPath)

>>> L1Path <<<

->HTR (ch)
E_T(L1Primitive: 8bits:non-linear)
->L1 LUT (ch)
E_T(4x4 HcTower: 8bits:linear)
->L1Calo
E_T(L1jets),Et(L1tau),Et(L1MET)
->L1CaloGlobal(Threshold (obj))
->L1Global
L1Trigger

>>> after DAQPath <<<

->ReadoutAnalyzer (ch)
E_T(channel)
->TowerCreator
E_T(Ec+Hc Tower)
->Jet/MET/tauReco
E_T(jetR),Et(tauR),Et(METR)
->EtCaloCorrection (obj)
(corr. for linearlity)
E_T(JetC),Et(tauC),Et(METC)
->EtPhysCorrection (obj)
(corr. for out-of-cone)
E_T(Parton)

Calibration/correction
(ch) - channel by channel
(obj) - phys. Obj, (jet, tau, MET)

Tools

A) Megatile scanner:
- Co^{60} gamma source
- each tile: light yield
- during construction
  - all tiles

B) Moving radio active source:
- Co^{60} gamma source
- full chain: gain
- during CMS-open (manual)
  - all tiles
- during off beam time (remote)
  - tiles in layer 0 & 9

C) UV Laser:
- full chain: timing, gain-change
- during off beam time
  - tiles in layer 0 & 9
  - all RBX

D) Blue LED:
- timing, gain change
- during the off beam time
  - all RBX

E) Test beam
- normalization between
  - GeV vs. ADC vs. A,B,C,D
- ratios: elec/pion, muon/pion
- before assembly
  - a few wedges

F) Physics events
- mip signal, link to HO
  - muon
- calo energy scale (e/pi)
  - charged hadron
- physics energy scale
  - photon+jet balancing
  - Z+jet balancing
  - di-jets balancing
  - di-jet mass
    - W->jj in top decay

>> non-linear response

>> pile-up effect

Scenario (HB/HE)

(same to HF)

1) Before megatile insertion
- megatile scanner: all tiles
- moving wire source: all tiles

2.1) After megatile insertion
- moving wire source: all tiles / 2 layer
- UV laser: 2 layers/wedge

2.2) After megatile insertion
- test beam: a few wedges.

→ Absolute calib. Accuracy of 2% for single particle

3) Before closing the CMS
- moving wire source: all tiles
- UV laser & blue LED: all RBX

(do 3, about once/year)

4) Beam off times
- moving wire source: 2layer/wedge
- UV laser: 2 laer/wedge
- UV laser & blue LED: all RBX

→ Monitor for change with time Accuracy < 1%

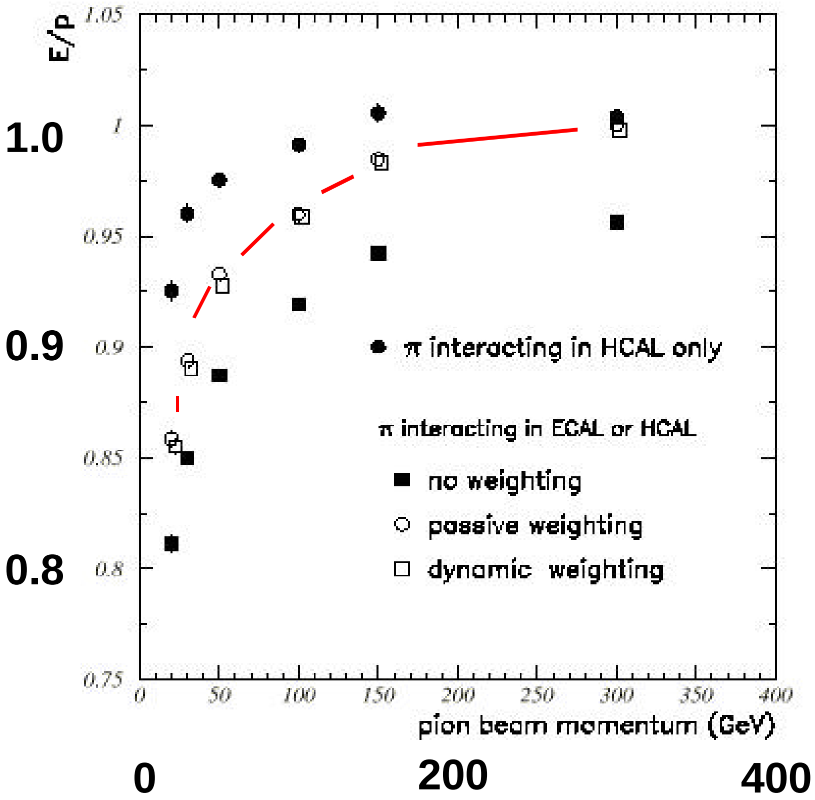
once/month

a few times/day (?)

5) Beam on (in situ)
- jets / tau / MET ECAL+HCAL

From Test Beam to CMS

Test beam data



(Lowest data point 20GeV)

Test beam data with wire source calibration will give energy scale at the begging of the CMS run.

But it has limitation-

Test beam environment does not have B-field and Tracker material.

>> We use MC, initially.

In order to verify MC, we need data points below 15GeV.

>> need "in situ calibration"

In Situ Calibration
(Physics Event Trigger)

A) Min-bias events trigger

- estimation of pile-up energy.
- normalization within each eta-ring. → 2% accuracy with 1k events in HF
- isolated low E_T charged tracks

B) QCD Jet trigger (pre-scaled)

- normalization within each eta-ring
- normalization at the HB-HE-HF boundary
- test on uniformity over full range.
- dijet balancing to normalize E_T scale in rings.

C) tau trigger

- isolated high Et charged tracks (Et>30GeV)

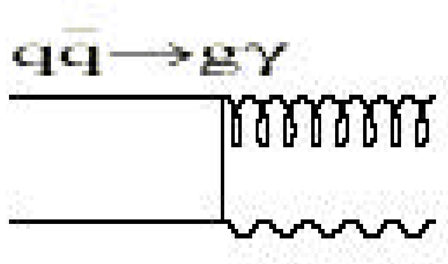
D) muon trigger (isolated)

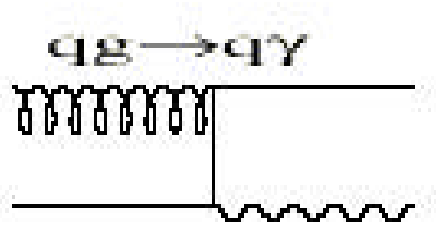
- good for monitoring.
- probably too small energy deposit for calibration.

In Situ Calibration (2)

E) 1 photon + 1 jet

- E_T Scale over full range by photon-jet balancing





Note:

- depend on ECAL Et scale
- sensitive to ISR (& FSR)

F) Z (-> ee, $\mu\mu$) + 1 jet

- E_T Scale over full range by Z-jet balancing

Note:

- depend on Tracker and/or ECAL
- sensitive to ISR (& FSR)

Photon-Jet balancing
for HF Jets

E.Dorshkevich,V.Gavrilov
CMS Note 1999/038

Using
Et(γ) > 40GeV, |η (γ)| < 2.4

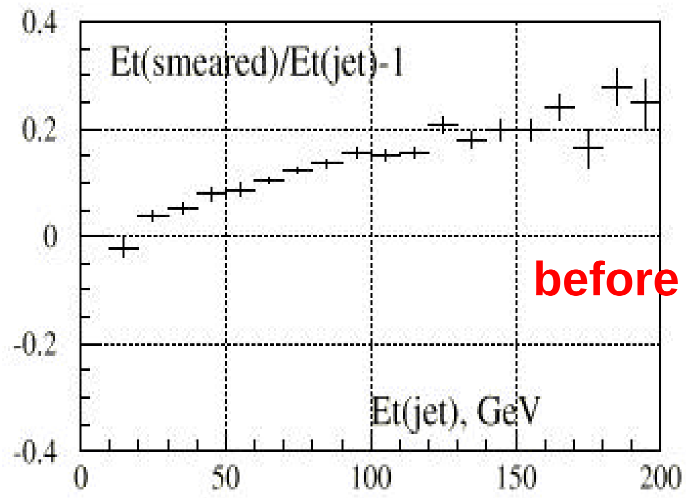
- minimize MET with 4000 γ

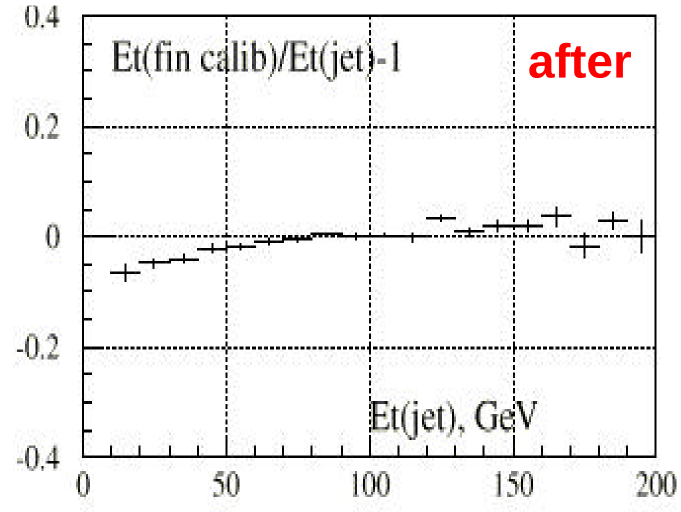
$$Et(calib) = C_{(S)}(\eta)\ Et_{(Short)} + C_{(L)}(\eta)\ Et_{(Long)}$$

- 2.3 days at 10E33 with 1% efficiency

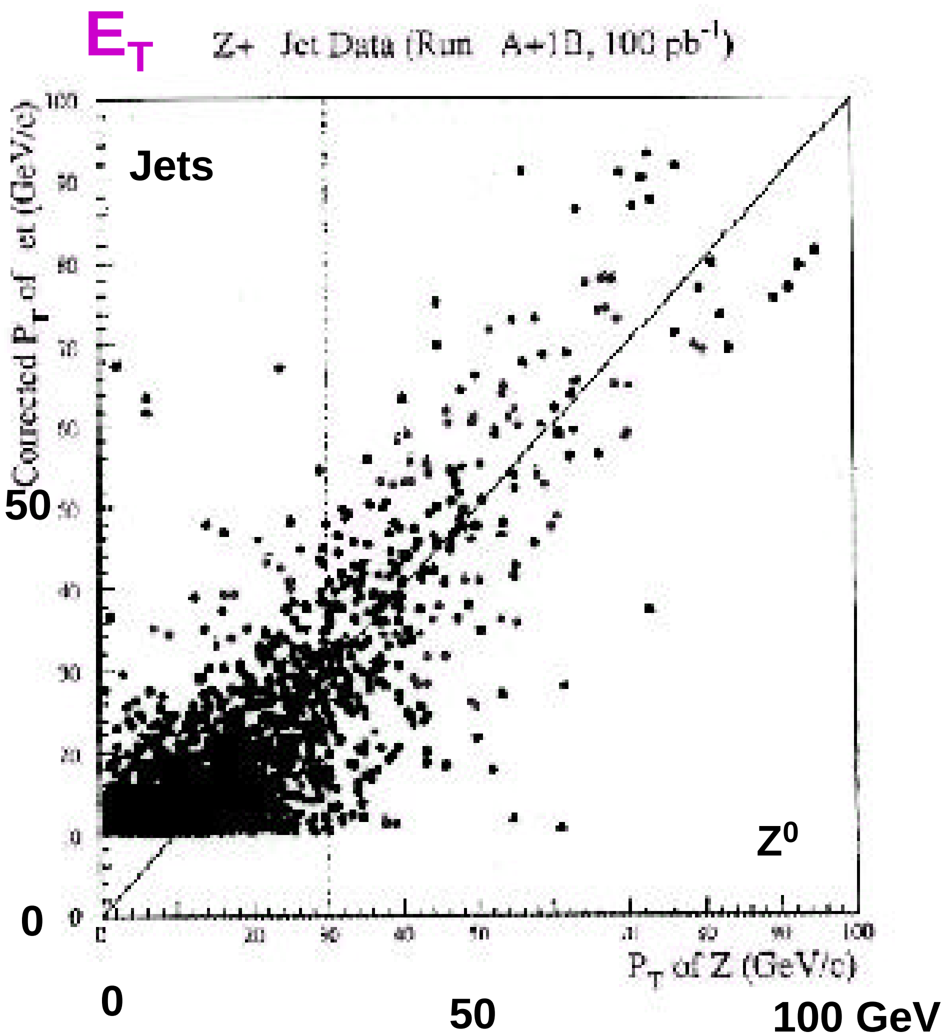
Accuracy < 1-5% for Et>40GeV

(tagging jets)





Z (ee,μμ) - jet balancing



Freeman & Wu (Fermilab-TM-1984)

CDF Data (100pb^{-1}) : energy scale accuracy to 5% for Et>30GeV

CMS:

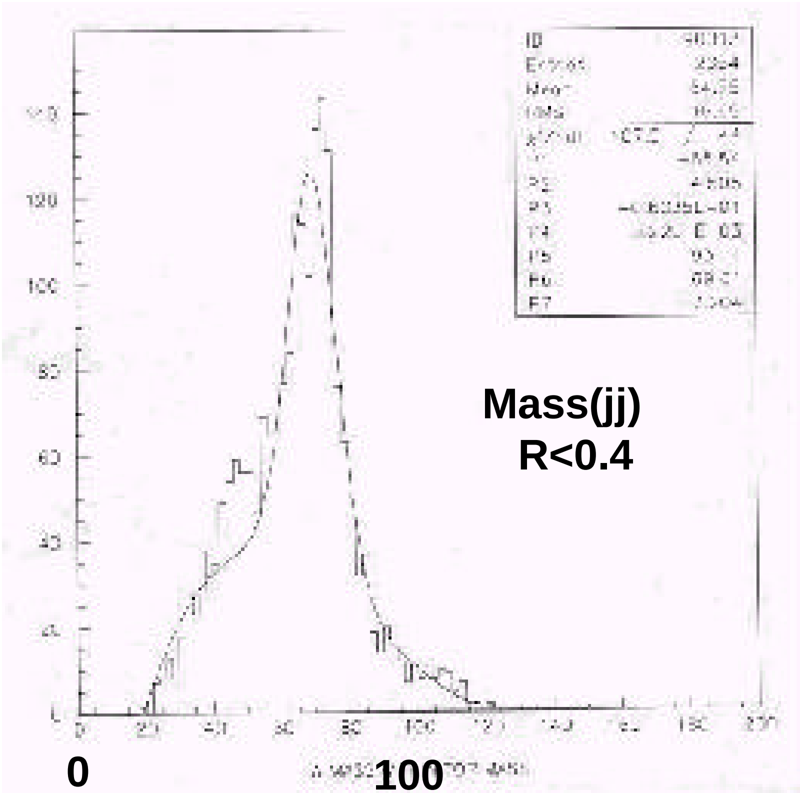
700k events/month at 10E33

|η (lep.)|<2.6
ET(jet)>40GeV

In Situ Calibration (3)

F) Top trigger (1 lepton + jets + 2 b-tags)

- E_T scale by Mass(jj) for W in Top decay.



Freeman & Wu (Fermilab-TM-1984)

Parameterized simulation

Peak: 69.6 GeV
sigma: 7.2 GeV

45000 events / month
at 10E33
with double b-tagging.

Not depend on ISR!

Scenario toward final ET scale

A) **No special event trigger during beam on.** (except for monitor runs)

B) **Min-bias and QCD events will be used to monitor the calorimeter through runs.**

C) **Four steps to determine E_T scale after the first run starts.**

1. **Test beam data and wire source (plus MC) gives initial scale.**
2. **In 1~3 months, improved E_T scale by physics events.**
   - **requires very intensive data analyses.**
     - **How soon data will be available for analyses?**
     - **How soon ECAL and MUON/TRACKER will give us calibrated E_T?**
3. **Development of algorithm for more improved E_T scale.**
   - **use of full shower shape, i.e. transverse shower shape in ECAL crystals as well as longitudinal shower shape.**
   - **use of tracks.**
     - **How easy to access to full detector information?**
4. **Apply the new algorithm for final results.**
   - **re-processing (some) events**
     - **How easy to reprocess events?**

Summary

Calibration consists of two parts-

- **From light to ADC signal.**
  - Wire source and test beam data will give initial energy scale.
  - Wire source to monitor change with time.
  - Laser and LED to monitor timing and gain 'continuously'.
  - Min-bias, QCD events to normalize E_T scale within eta ring.
    - **usable before ECAL/TRACKER calibrations are established.**
- **From ADC signal to Jets/MET/Tau**
  - in-situ calibration
    - **dijets, photon-jet, Z-jet, dijets from W in top events**
    - **move lower Et to higher Et as statistics increase.**
    - **no special run is required, but timely data analysis will be required.**
  - Monte Carlo Simulation: try less depend on MC

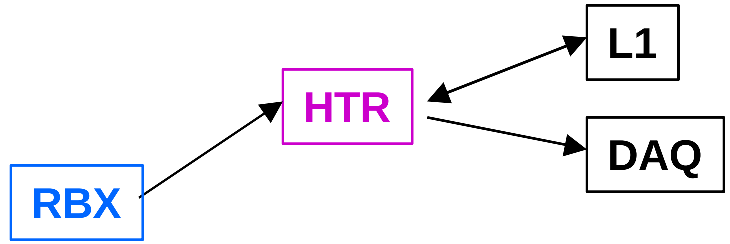
A lot of fun tasks are waiting for us!

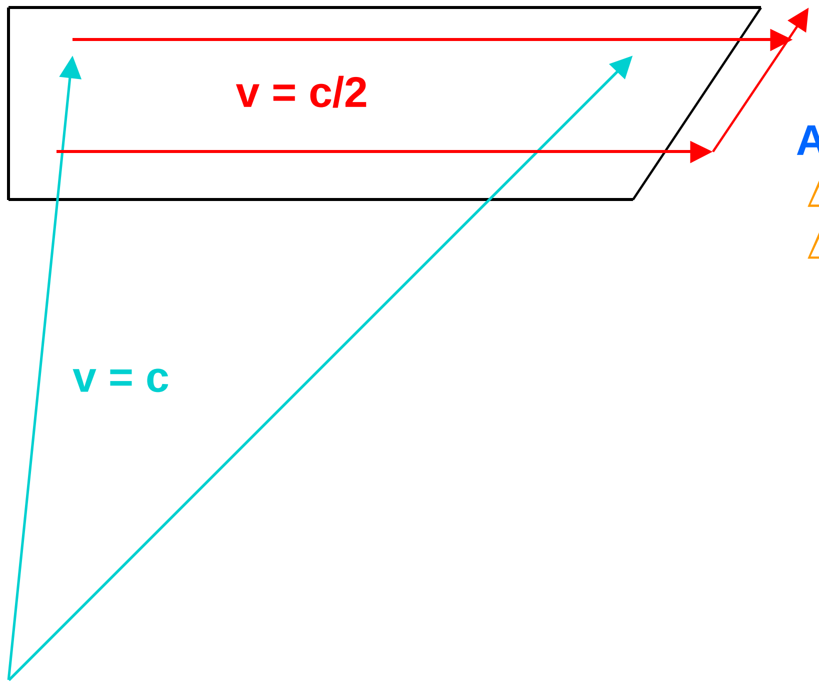
HCAL Timing Calibration

(addition to talk given on 26-sep-2000)

HCAL Timing Calibration

1) Time variation within a wedge (a RBX)





Arrival time of lights at RBX in HB

Δ t = 2 nsec (layer-layer in a tower)

Δ t < 15 nsec (tower-tower in a wedge)

Smaller for HE, HO, HF

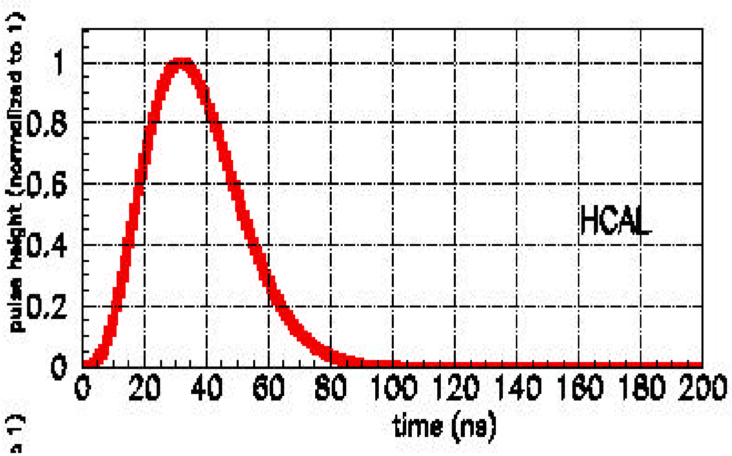
36 RBXs in HB
36 RBXs in HE
<(12+32) RBXs in HO
36 RBXs in HF

2) Synchronization (global)

L1 data, L1 accept (pointer to pipeline), 40MHz clock

Time Correction in and among RBX

HCAL Pulse (in ORCA4)



HCAL time constants

11 ns: w.l.s. fiber
12 ns: HPD collection time
25 ns: QIE

4 ns shifts -> 1% error in Et meas.

QIE clock control ASIC

clock skewing by 1ns over 25ns

Method

initial variation ~10ns in hardware construction.

- Laser pulse to all tiles (20Hz).

- Monitor by reading out 5 time slices and histograming the sharing fractions.

Adjust individual timing to accuracy = 2~4 nsec.

Synchronization (Global)

Correction for variation in

- **Data cable length**
- **TTC distribution**

Adjustable knobs

- **QIE (1ns step)**
- **HTR timing to L1 regional crate**
- **L1 accept pointer to pipeline**

Use trigger 1 crossing after the abort gap.

- **read out all channels, 10 times/channel**
- **histograming to find right bucket**
- **adjust L1 pointer to correct bucket.**

about O(weeks) to check all channels at 10E32